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Material - Titanium - Ti 13V-11Cr-3Al (B120VCA)

Shear Strengths of Rivets at Sub-Zero Temperatures

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Abstract:

Annealed, 3/16" diameter, flat head Ti 13V-11Cr-3Al rivets were driven into single lap joints of Ti 4Al-3Mo-1V, 0.063" thick sheet which was heat treated to 190 ksi ultimate tensile strength. Each joint contained two tandem rivets spaced 3/4" apart and held 3/8" from the edge of the joint. The yield and ultimate rivet loads observed were as follows:

Temperature	Yield Loads, lbs.*	Ultimate Load, lbs.*
80°F	2736	3070
-65°F	2842	3382
-110°F	3138	3573
-320°F	2283	2348

* per rivet, single shear condition.

Reference: Stier, H., Bergstedt, P. W., Turner, H. C., "Shear Strength of B-120 VCA Titanium Rivets at Sub-Zero Temperatures," General Dynamics/ Convair Report MP 59-226, San Diego, California, 3 November 1959. (Reference attached).

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3 pages, 1 table

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A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO

STRUCTURES-MATERIALS LABORATORIES

REPORT MP-59-226
DATE 3 November 1959
MODEL S.R.P.

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MODEL: S.R.P.

CONTRACT NO. AF 33(600)-34876

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Report No. MP-59-226
Shear Strength of B-120 VCA Titanium Rivets at Sub-Zero Temperatures

OBJECT:

To determine the shear strength of B-120 VCA titanium rivets at sub-zero temperatures.

CONCLUSIONS:

The shear strength of the B-120 VCA titanium rivets is better at -65°F and -110°F than at room temperature. At -320°F the shear strength is reduced to approximately 75% of the room temperature strength.

The B-120 VCA rivets have a pronounced tendency to snap off the heads at the sub-zero temperatures. The type of failure at the ultimate load changes from rivet shear at room temperature to snapping off of rivet heads at -65°F and -110°F. At -320°F failure occurs simultaneously under the heads and in the shank of the rivets.

TEST SPECIMENS:

The rivets provided for this test were identical to the rivets discussed in report MP-58-262; viz., 3/16" dia. flat head rivets of B-120 VCA titanium which had been cold-headed in the annealed condition. All rivets were vacuum annealed after manufacture, except those in specimens #4 and #6 which were annealed in air and then pickled in HF + HNO_3 to remove scaling. For the vacuum treatment, the rivets were sealed in a Vycor glass tube at a pressure of about 3 microns of mercury, heated to 1450°F for 30 minutes, and air cooled. One of the Vycor tubes broke during heat treatment and the rivets became scaled. A few of these scaled rivets were pickled and driven in specimens #4 and #6.

The shear specimens were single lap-joints with two tandem rivets spaced along the longitudinal center-line of the joint. Rivets were spaced 3/4" apart and 3/8" from the edge of the sheet. Sheets were .063" thick titanium alloy Ti-4Al-3Mo-1V heat treated to 190 ksi. Rivet shanks protruded 1.14 diameters before driving. All rivets were squeezed in a compression riveter except for one rivet in specimen #6 which was gunned. The rivets were driven with a flat set in both methods.

TEST PROCEDURE:

The shear specimens were pulled in a 120,000 pound Tinius-Olsen tensile machine and the yield strength of the joints determined as in report MP-58-262. Extensometer arms clamped to the specimen passed through the roof of the cold-chamber to an S-1 microformer which recorded a load-extension curve for the lap-joint being pulled. The curves started at the minimum tare load of about 1000 pounds which was required to overcome erratic behavior of the extensometer due to bending of the joint under load. The yield load was taken by measuring an offset from the straight-line portion of the load-extension curve; the offset corresponded to a permanent set of .005".

TEST PROCEDURE: (Continued)

The -65°F temperature was achieved by circulating cold air through the cold chamber; -110°F by filling the chamber with a mixture of dry ice and alcohol; -320°F by filling the chamber with liquid nitrogen.

RESULTS & DISCUSSION:

The shear strength at room temperature for the B-120 VCA titanium rivets in titanium sheet Ti-4Al-3Mo-1V was nearly that found in previous tests of B-120 VCA rivets in 4130 steel sheet (see Report MP-58-262).

	Room Temperature Shear Strength of Vacuum-Annealed B-120 VCA Rivets	
	Ave. Yield Load, #/Rivet	Ave. Ult. Load, #/Rivet
In 4130 steel sheet	2810*	3135*
In Ti-4Al-3Mo-1V sheet. . . .	2736	3070

*From Report MP-58-262 for rivets vacuum annealed after cold-heading.

In both tests the sheet material was .063" thick and had been heat treated to about 190 ksi. Also, in both tests the rivets had been vacuum annealed after cold-heading and prior to driving. In both tests ultimate room-temperature failure occurred by rivet shear (except for one rivet of this test which failed by snapping off the manufactured and the driven heads).

At -65°F and -110°F the shear strength of the B-120 VCA rivets increased, as shown in Table I. At these temperatures the rivets showed a pronounced tendency to snap off the heads. The snapping of heads may be related to increased notch-sensitivity at the low temperatures. At extremely low temperature (-320°F) the shear strength fell below the room temperature strength. Microscopic examination of rivets which failed at -320°F showed failure occurring simultaneously under the heads and at various points in the shank in addition to shearing at the interface of the lap-joint. The failure cracks had a jagged, step-like appearance within individual grains indicating that failure had occurred on crystallographic planes within the grains at -320°F.

A visual examination of driven heads revealed a small number of rivets which were rejectably cracked according to established standards for conventional rivets (Convair MPS-46.05D). Table I shows that vacuum-annealed B-120 VCA rivets squeezed to 1.66 diameters or gunned to 1.50 diameters showed rejectable cracks in 5 out of 24 rivets. There was no need to drive the rivets to 1.66 diameters; in fact, rivets driven to 1.33 diameters in Report MP-58-262 showed the same strength with no rejectable cracked heads.

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* per rivet, single shear condition

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TABLE I. RESULTS OF SHEAR TESTS OF RIVETED LAP-JOINTS INCORPORATING PROTRUDING HEAD B-120VCA TITANIUM ALLOY RIVETS IN Ti-4Al-3Mo-1V SHEET (a) AT 80°F, -65°F, -110°F, and -320°F.

Identif.	Nominal Rivet Diam. (inches)	Rivet Driving Method	Condition of Driven Heads	Driven Head Diam. (inches)	Heat Treatment of Rivets	Temperature of Test	YIELD LOAD #/rivet	ULTIMATE LOAD #/rivet	FAILURE NOTES
7-7	3/16	Squeeze	Non-reject cracks	.317-.319	Vacuum anneal(b)	80°F	2713	3210	Holes in sheet not deformed. Rivets sheared at interface of lap-joint.
10-10	"	"	2 rivets rejectable	.306-.320	" "	"	2625	2720	Sheet not deformed. One rivet sheared at interface of lap. Other rivet snapped off mfg. & driven heads.
11-11	"	"	Non-reject cracks	.316-.321	" "	"	2870	3280	Holes in sheet not deformed. Rivets sheared at interface of lap-joint.
						Average	2736	3070	
9-9	3/16	Squeeze	No cracks	.314-.318	Vacuum anneal(b)	-65°F	3205	3805	Holes in sheet not deformed. No rivets found after test.
6-6	"	Gun(d)	1 rejectable (gunned) / 1 non-rej. cracks (gunned)	.287-.317	Anneal in air(c)	"	2320	2700	Slight initial sheet brg. failure. One rivet snapped off mfg. head & broke off parts of driven. Other rivet not found.
8-8	"	Squeeze	Non-reject cracks	.319-.322	Vacuum anneal(b)	"	3000+	3640	Sheet brg. failure with elongation of holes in sheet. One rivet snapped off driven head. Other rivet not found.
						Average	2842	3382	
12-12	3/16	Squeeze	1 rivet no cracks / 1 " non-rej. cracks	.308-.313	Vacuum anneal(b)	-110°F	3240	3415	Initial sheet brg. failure. One rivet snapped off mfg.& driven heads. Other rivet not found.
3-3	"	"	1 " non-rej. cracks / 1 " rejectable	.321-.322	" "	"	3225	3530	Initial sheet brg. failure. One rivet snapped off mfg. head. Other rivet not found.
2-2	"	"	1 " rejectable / 1 " non-rej.	.295-.309	" "	"	2950	3775	Initial sheet brg. failure. Two rivets snapped off mfg.& driven heads.
						Average	3136	3573	
1-1	3/16	Squeeze	No cracks	.307-.309	Vacuum anneal(b)	-320°F	2500+	2563	Slight brg. fail. in sheet. All rivet heads snapped (mfg.& driven). Also, some rivets sheared at interface of lap joint.
5-5	"	"	Non-rej. cracks	.313-.315	" "	"	2150+	2170	No deformation of holes in sheet. Both rivets sheared at interface of lap-joint. Both driven heads snapped off and one mfg. head snapped off.
4-4	"	"	" " "	.302-.320	Anneal in air(c)	"	2200+	2210	Slight brg. fail. in sheet. One rivet sheared at interface of lap-joint and snapped off its driven head. One rivet snapped both its mfg.& driven heads but did not shear at interface of lap-joint.
						Average	2283	2348	

(a) Thickness 0.063"; heat treated to 190,000 psi.
Titanium Metals Corp. of America, Heat number M-8013, Sheet number 37C-1-M.

(b) Rivets were manufactured from B-120VCA titanium wire in the annealed condition and were vacuum annealed after manufacture (1450°F, 30 minutes, air cool)

(c) Rivets were manufactured from B-120VCA titanium wire in the annealed condition and were re-annealed in air & pickled after manufacture (1450°F, 30 minutes, air cool) Pickle is $HF+HNO_3$.

(d) One rivet gunned with pneumatic rivet gun; other rivet squeezed in pneumatic compression riveter.